The Engineering News.

MARCH, 1875.

The Manner of carrying on the United States Survey of the great Lakes.

[CONCLUDED.]

V.—MAGNETIC OBSERVATIONS.

These observations are usually made by the astronomical parties, and consist in determining the dip and declination of the needle and the magnetic intensity at each point occupied by the astronomical parties. The instruments used are the declinometer and dip circle.

VI.—GAUGING THE OUTFLOW OF THE LAKES.

Parties were stationed on the St. Mary's River, below the falls, the St. Clair River, the Niagara River and the St. Lawrence River. The following is a description of the mode of gauging the St. Clair River.

The St. Clair River at the place chosen was about 1.700 feet wide. A base line 700 feet long and parallel to the axis of the current was chosen, and at its extremities posts were sunk into the ground for the theodolites to rest upon. Near each of these posts was placed another post, on which were a relay or sounder and a talking key, and at one extremity of the line was placed a chronometer. The two extremitities of the base line were then connected with a wire and small battery. On the opposite shore two flags were set up so that the lines joining them and the opposite station of the base line should be perpendicular to the direction of the current.

Then a float being set off at any desired distance from either shore from a boat anchored far enough above the upper station to allow it to assume a uniform motion, the assistant at the upper station directed the telescope of his theodolite on the opposite flag. Just as the float reached the field of his glass he gave an alarm with his key and caught the beats of his chronometer. Then, with his hand on the key and counting the chronometer beats, he watched until the float reached the vertical cross-hair of his telescope, when he closed the circuit and recorded the time of passage. The assistant at the lower station at the first alarm turned his telescope upon the float and followed it until the single tick showed him that it had reached the upper line; he then read and ecorded the angle, and then turned his telescope upon the lower flag. He in turn, as the float approached the line, gave the alarm and single tick as it passed, and the first assistant at the alarm turned his telescope upon the float and counted the chronometer beats until the tick told him that it had passed the lower line, when he noted the time and recorded it together with the angle. Both the angles were read from the direction of the base line.

In this manner the times of passage of the float across the lines joining the stations and flags were obtained to the nearest second, and the place of passage within a foot. After a series of floats had been put out at different depths, the boat was moved to another position farther from or nearer to the base line, and another series taken.

The lower part of the float was an old paint keg with the bottom knocked out and with a reel inside of it with as much small cord as was necessary wound upon it. This cord was marked every five feet and passed up through a small hole in a leather strap riveted on the top of the keg.

The upper part of the float was made of tin in an ellipsoidal form. Through its axis was run a wire, projecting below about four inches, at which end was attached the cord joining the upper and lower float, and above about eight inches, at which end was fastened a small flag two inches wide and six inches long. By lengthening or shortening the cord joining the upper and lower floats, the velocity at different depths of the stream was ascertained.

The cross-sections of the river at the upper and lower stations were carefully determined by means of careful soundings on the lines joining each station and its opposite flag, the position of each sounding being carefully located by intersections from the base station.

During the time the parties were engaged meteorological observations, including the height of water, were carefully taken every two hours.

A system of vertical planes parallel to the base line 200 feet apart were conceived to pass dividing the river into divisions. The divisions nearest the shore were again subdivided. The mean velocity in each division was then computed from the field data. The discharge in each division per second for any day was the product of the mean of the upper and lower areas of each division by the mean daily velocity of the current in that division, plus or minus the correction of height of water for each day. Adding together the discharges of the several divisions, the result was the discharge per second of the river for that day.

Knowing the area of country drained into a lake and ascertaining by observations taken at a sufficient nnmber of points within that area the amount of rainfall over the area and the amount of discharge at the outlet of the lakes, many useful problems may be solved, if the observations be kept up for a length of time.

It is estimated that about one-fourth of the rainfall is absorbed by the vegetation and another one-fourth evaporated before it reaches the outlet of the lakes, leaving about one-half of the rainfall to be discharged at the outlet of the lakes.

VII.—METEOROLOGICAL OBSERVATIONS.

These are conducted at various stations on the lakes, and consist in observations with the barometer, thermometer, tide gauges, evaporators and rain gauges. In some cases the tide and wind instruments are self-registering. These observations are reduced and tabulated. One of the results has been the ascertaining of the existence of tides of the same nature as those on the ocean. As these observations increase and are carefully digested and compared with like observations at other points, there will doutbtless be many interesting problems in natural science determined. The daily heights of water as shown by the tide-gauges serve to reduce all the hydrography of each lake to a reference to one plane.

VIII.—CHART-MAKING.

After the in-shore and off-shore parties have mapped their work, the detailed maps, together with the computed results of the astronomical and primary triangulation work, pass into the hands of the draughtsmen whose duty is to reduce and combine them. In making the final charts, the draughtsmen first determine the middle meridian and parallel of latitude. The projection is then made on the surface of a cone tangent on the earth's surface along the middle parallel of latitude. The cone is then developed on the plane of the paper. The meridians appear at right lines, and the parallels of latitude are arcs of circles. The scales on which the maps are made are, for charts of whole lakes, 1-400,000; for localities such as large bays, 1-120,000; for harbors, etc., 1-80,000; and for rivers such a scale as will give room for showing all bars, etc., plainly. On each chart is given, by lines and by precepts, sailing directions; and, as the soundings written on the maps are all referred to the same plane, a water table is given, showing the heights of water refered to this plane during the season of navigation for a series of years. The variations of the magnetic from the true meridian for the various localities on the map for the years in which they were determined are also tabulated, and if any periodical change of variation has been ascertained, this also is recorded. Thus it will be seen that the information gathered by all parties is in some form or other finally recorded on the final charts of the lakes.

When one comes into possession of one of these charts of any of the Great Lakes, he little imagines the amount of labor and expense the government has been to furnish a sure guide for the mariner.

Fires from Defective Flues.

One of the most frequent and dangerous causes of conflagration in dwelling houses during the winter season, is the close contact of timbers to concealed furnace flues. Every year we have this subject brought prominently to the public notice by the destruction of much valuable property, and not infrequently the loss of life, and yet builders do not seem to observe the necessary precautions, and householders are, apparently, as indifferent as ever to a danger which is all the more to be dreaded because unseen. Fires attributed to "defective flues" are more often attributable to hte defective setting of flues, resulting from ignorance or carelessness on the part of builders and contractors. A careful investigation would generally show that there was no defect in the flue proper, but that they were placed in close proximity to well seasoned wood work. As the rule, the furnaces put in city houses are too small. They answer very well in moderate weather, but in very cold weather they have to be driven beyond their proper capacity, the flues connecting with the registers become overheated, timbers previously charred take fire, the danger is not discovered until too late, and before the point of ignition can be reached by a stream of water the fire may have gained so much headway as to be beyond control. We know of one large building, destroyed not long ago by fire, in which the hot air was conveyed to the registers from the furnace in pine boxes lined with tin. In this case the plea of a "defective flue" was well founded.

In all buildings particular care should be taken to have an open space between the flues or pipes, by which hot air is conducted, and the wood work, and were this precaution observed fires originating with the flues would be of rare occurrence. The experience of fire insurance agents, and others whose business it is to investigate the causes of fires, goes to show that in many instances they arise from the fact that the beams which support flooring are made to rest either in the brick work of the flue, or close against it The use of a trimmer beam, by which this could be avoided, entails a little extra expense, and many of those who build houses by contract, or on speculation, unless specially watched, will not use it. After the house is completed, and all the work on it closed in, it is hardly possible for the insurance inspector to tell whether this condition of safety has been complied with or not, and hence many houses are judged to be safe that are really dangerous. It is manifest that wood-work in such close contact with hot air flues will, in a short time, become as dry as tinder, and liable at any moment to ignite, and the great danger to those who occupy dwellings built in this way consists in their ignorance of what is always impending over them. Fires sometimes occur from breaks in hot air pipes, produced either by rust or other cause, and a frequent and careful inspection of their condition should be made. Steam pipes, also, have been occasionally the cause of fire by being in too close contact with the wood work of buildings, although instances of this kind are of rare occurrence. Some years ago a fire in a Broadway building was traced directly to the action of a steam pipe, producing such a state of dryness in the partition to which it was attached as to cause it to ignite. In very many cases fires do their work so thoroughly as to destroy all evidence of the condition of the flues and heating apparatus, and may be sometimes attributed to the defects there which did not exist, but it is beyond doubt that a large proportion of those that occur, especially in dwelling houses, arise from the culpable negligence of the builder in not adopting the proper methods of prevention.

There are no such difficulties connected with this matter as are involved in the proper method of ventilation; the conditions of safety are well known to builders, and when fires occur through their neglect of the proper precautions, there ought to be some means of bringing home the responsibility in such a way as would compel their observance of more careful methods of construction. The ordinary furnaces, steam heaters and stoves used in our dwellings, are not necessarily dangerous, if sufficient space is allowed between the pipes and the woodwork to permit the free circulation of air, and fires which occur from the neglect of this simple precaution can only be the result of a gross neglect of duty on the part of those who could prevent them if they would—*The Iron Age.*

Science and the Telegraph, Steam Engine, and Chronometer.

We live in a period of which a characteristic is the supplanting of human and animal labor by machines. Its mechanical inventions have wrought a social revolution.

That a piece of amber, when rubbed, will attract and then repel light bodies, was a fact known six hundred years before Christ. It remained an isolated, uncultivated fact, a mere trifle, until sixteen hundred years after Christ. Then dealt with by the scientific methods of mathematical discussion and experiment, and practical application made of the result, it has permitted men to communicate instantaneously with each other across continents and under oceans. It has centralized the world. By enabling the sovereign authority to transmit its mandates without regard to distance or to time, it has revolutionized statesmanship and condensed political power.

In the Museum of Alexandria there was a machine invented by Hero, the mathematician, a little more than a hundred years before Christ. It revolved by the agency of steam, and was of the form that we should now call a reaction-engine. This, the germ of one of the most important inventions ever made, was remembered as a mere curiosity for seventeen hundred years.

Chance had nothing to do with the invention of the modern steam-engine. It was the product of meditation and experiment. In the middle of the seventeenth century several mechanical engineers attempted to utilize the properties of steam; their labors were brought to perfection by Watt in the middle of the eighteenth.

The steam-engine quickly became the drudge of civilization. It performed the work of many millions of men. It gave, to those who would have been condemned to a life of brutal toil, the opportunity of better pursuits. He who formerly labored might now think.

Its earliest application was in such operations as pumping, wherein mere force is required. Soon, however, it vindicated its delicacy of touch in the industrial arts of spinning and weaving. It created vast manufacturing establishments, and supplied clothing for the world. It changed the industry of nations.

In its application, first to the navigation of rivers, and then to the navigation of the ocean, it more than quadrupled the speed that had heretofore been attained. Instead of forty days being requisite for the passage, the Atlantic might now be crossed in eight. But, in land transportation, its power was most strikingly displayed. The admirable invention of the locomotive enabled men to travel more in less than an hour than they formerly could have done in more than a day.

The locomotive has not only enlarged the field of human activity, but, by diminishing space, it has increased the capabilities of human life. In the swift transportation of manufactured goods and agricultural products, it has become a most efficient incentive to human industry.

The perfection of ocean steam-navigation was greatly promoted by the invention of the chronometer, which rendered it possible to find with accuracy the place of a ship at sea. The great drawback on the advancement of science in the Alexandrian School was the want of an instrument for the measurement of time, and one for the measurement of temperature —the chronometer and the thermometer; indeed the invention of the latter is essential to that of the former. Clepsydras, or water-clocks, had been tried, but they were deficient in accuracy. Of one of them, ornamented with the signs of the zodiac, and destroyed by certain primitive Christians, St. Polycarp significantly remarked, "In all these monstrous demons

is seen an art hostile to God." Not until about 1680 did the chronometer begin to approach accuracy. Hooke, the contemporary of Newton, gave it the balance-wheel, with the spiral spring and various escapements in succession were devised, such as the anchor, the dead-beat, the duplex, the remontoir. Provisions for the variation of temperature were introduced. It was brought to perfection eventually by Harrison and Arnold, in their hands becoming an accurate measure of the the flight of time. To the invention of the chronometer must be added that of the reflecting sextant by Godfrey. This permitted astronomical observations to be made, notwithstanding the motion of a ship.—*Prof. Draper.*

Technical Education.

There is evidently a growing interest in this country in the subject of technical education. In many trades in which theoretical knowledge has hitherto been held of little account compared with practical experience, the idea is steadily gaining ground that the theory and practice must go together to insure the attainment of the fullest measure of success. The chemist, the physicist, the civil and mechanical engineer, the scientific metallurgist, all find opening before them a wider field of usefulness, as manufacturers in one trade after another call upon them for advice and assistance in perfecting methods and processes now in use, or in devising others which shall be better and more economical. Scientific men are no longer regarded by "practical men" as mere theorists, from whom nothing useful can be learned which is worth a consultation fee. The practical men have learned from experience that there is something in theory when reduce to a practical application, and that a judicious expenditure of money in scientific investigation and experiment is always a good investment. The next step, which many have already takcn, is to give their sons educational advantages which they did not have themselves, by sending them to one of the few technical schools of this country, or one of the many and excellent institutions of this kind in Europe. The next step, let us hope, will be the development of a strong public sentiment in favor of extending the advantages of technical education to the classes in this country which cannot afford to go abroad, or to pay much for tuition at home—the classes from which our intelligent native-born mechanics are drawn. To do this would be to insure to the country the fullest measure of future prosperity. We have varied natural resources, capable of sustaining an annual production of useful commodities as any other country of the world, our inventors are ingenious and practical, our working classes, recruited by the immigration of young and ambitious men from abroad, tempted hither by higher wages and larger opportunities, compare more than favorably with those of other countries, and we have enough of both capital and enterprise to carry on great manufacturing industries. With these advantages, another generation should build a vast industrial prosperity upon the foundations already laid, and if, in the education of that generation, we combine the learning of the school with the practical instruction of the workshop and factory, the progress of the next half century will be greater and more rapid than that which the country has witnessed during the past fifty years. It will not do, however, to rely too much upon natural advantages, or to neglect any of the means which experience has shown to be best calculated to render a people capable of making the most rapid progress in the application of the practical arts and sciences which internal resources or external circumstances may render possible. Among these means none are more certain to accomplish important results than abundant facilities for technical instruction. In the lack of such facilities our educational system is essentially defective. In a country which aspires to industrial pre-eminence, brains must stand at the loom and intelligence at the work bench. The practical education of shop and factory is of the utmost importance so far as it goes, but it does not give the average mechanic a knowledge of his trade. No man is a good mechanic who is not fit to become a master, and no one can become a successful master who does not know the theory as well as the practice of his trade.

But we have no system of technical instruction in this country adapted to the wants of the people at large. How this want can best and most quickly be met, without detriment to our existing public school system, is a question which we think should receive the attention of those who make educational problems a study. There is nothing impracticable in the idea of a system of scientific and technical instruction which shall be practically free to all who wish to avail themselves of the facilities offered. Great polytechnic schools like those of Europe, are not to be looked for as the first fruits of a movement in this direction. Let us first have free evening classes and lectures in suitable buildings, to which young mechanics are invited. Under the charge of competent professors these classes would accomplish great good, and out of such a beginning would soon grow a system of public instruction well calculated to elevate the standard of intelligence among our working classes, and encourage a taste for reading and study on the part of young men who can be made to appreciate the advantages of education in no other way. The great work accomplished by the free classes of the Cooper Union, in this city, always full, shows that such a system as we have suggested would not fail for want of public appreciation.—*The Iron Age.*

Economical Consumption of Fuel.

G. F. Becker, in an address before the Royal School of Mines, Berlin, says:

"The progress in the economical consumption of fuel in the last fifty years has been enormous, and has been affected in great part by metallurgists; and here again we find the scientific men taking the lead. In the economical application of the heat developed by fuel, the Bessemer process is enormously effective, not more than ten pounds of coal being requisite for the production of a hundred-weight of steel from pig-iron by this method, while in the older process, still in use for fine qualities of steel, two hundred and fifty pounds are needed. Siemens, by making the heat which would escape through the the chimney of an ordinary furnace warm the fuel and the air necessary to combustion, obtains an economy of two thirds the weight of fuel. It was Faber du Faur, an accomplished Bavarian metallurgist, who first made practical use of the gases which formerly escaped in immense quantities from the top of blast-furnaces and the enormous blast-engines, the hoisting-engines, pumps, and hot-blast stoves, often even the roasting kilns of such establishments nowadays require no fuel except this long-neglected waste product. Bischof, another German engineer and metallurgical author, was the first to produce gas artificially for smelting purposes, and this was certainly one of the greatest advances ever made in our art. By first turning it into gas, fuel can be much more perfectly consumed than in the solid form, and hence can be made to give us, as in the Siemens furnace, in which only gas is used, a much higher temperature than is practically attained by the combustion of coal in the ordinary way; but perhaps the greatest advantage of gas is that subsistences in general scarcely regarded as fuel at all can be employed for the production of gas with the most brilliant results, a matter of the greatest importance, especially in a region destitute of true coal like California. Lundin, a noted and thoroughly educated Swedish metallurgist, has taught us how to produce gas from wet sawdust entirely without preparation, of such power that wrought iron may be melted with it, and the great difficulty is to find any material infusible enough to answer as a lining in the furnaces where it is consumed. You will receive some idea of the importance of these improvements from the fact that the economy in fuel effected in England alone in the year 1872, as compared with 1871, by the progress made in the introduction of more perfect apparatus represented more than four millions of tons of coal.

Telemeter Surveying.

Any one who has had experience in the use, on preliminary railroad surveys, of the "Telemeter Attachment to the Surveyor's Transit," as described in a paper published in the *Gazette* of January 2, (and in the *Engineer, Arehitect, and Surveyor* of Dec., 1874), would doubtless confer a favor on many members of the engineering profession by communicating the results of his experience and describing his mode of operating.

More than two years ago I sketched a plan of operations for such a survey, but, unfortunately, have never had an opportunity to test the advantages of the proposed plan. I think that by the use of a transit fitted with telemeter wires and an arc for measuring vertical angles it is possible to make satisfactory preliminary surveys and obtain reasonably accurate notes for map and profile at a cost much less than that of the common method of making surveys.

I venture to send a table of divisors for correcting telemeter observations taken at an angle of elevation or depression, so as to obtain the true horizontal distance.

In making the table I have assumed that the wires used for making the observations are so placed as to intercept a half foot on the rod for each 100 feet of distance; or, in other words, that the angle formed by the visual lines passing through the wires is (nearly) seventeen minutes.

Let a be the position of the observer and A that of the rod.

Let $b\ c$ be the distance on the rod intercepted by the visual lines passing through the telemeter wires when the observation is taken at an angle of elevation or depression, and $b'\ c'$ the corresponding distance if the observation were taken at a level. It is required to find the ratio between $b'\ c'$ and $b\ c$.

Let E=the angle at which the observation is made. In the figure $E=c\ a\ c'$.

Let v=the angle $b\ a\ c=b'\ a\ c'$. The lines $b\ a$ and $c\ a$ represent the visual lines passing through the telemeter wires.

It is evident that $b'c'=a\ c'$ tan. v, and $b\ c=a\ c'$ [tan. $(E+v)$ − tan. E]. Whence $\frac{b\ c}{b'c'} = \frac{tan.\ (E+v)-tan.\ E}{tan.\ v.}$

Represent this ratio by R: then $\frac{bc}{b'c'} = R$, whence $\frac{bc}{R} = b'\ c'$.

The table below is formed by giving different values to E in the equation $R = \frac{tan.\ (E+v)-tan.\ E}{tan.\ v.}$ when v is taken as 17 minutes.

From the preceeding discussion the use of the table is, I think, too evident to require explanation.

E	R	E	R	E	R	E	R	E	R
0°.00′	1.000	6°.	1.012	12°	1.046	18°.	1.107	24°	1.201
10	1.000	10	1.012	10	1.048	10	1.110	10	1.204
20	1.000	20	1.013	20	1.049	20	1.112	20	1.207
30	1.000	30	1.014	30	1.050	30	1.114	30	1.210
40	1.000	40	1.014	40	1.052	40	1.116	40	1.214
50	1.000	50	1.015	50	1.053	50	1.118	50	1.217
1.	1.000	7.	1.016	13	1.054	19	1.121	25	1.220
10	1.000	10	1.016	10	1.056	10	1.123	10	1.224
20	1.001	20	1.017	20	1.057	20	1.125	20	1.227
30	1.001	30	1.018	30	1.059	30	1.127	30	1.231
40	1.001	40	1.019	40	1.060	40	1.130	40	1.234
50	1.001	50	1.020	50	1.062	50	1.132	50	1.237
2.	1.001	8.	1.021	14	1.063	20	1.134	26	1.241
10	1.002	10	1.021	10	1.065	10	1.137	10	1.244
20	1.002	20	1.022	20	1.067	20	1.140	20	1.248
30	1.002	30	1.023	30	1.068	30	1.142	30	1.252
40	1.002	40	1.024	40	1.070	40	1.145	40	1.255
50	1.003	50	1.025	50	1.072	50	1.147	50	1.259
3.	1.003	9.	1.026	15	1.073	21	1.149	27	1.263
10	1.003	10	1.027	10	1.075	10	1.152	10	1.267
20	1.004	20	1.028	20	1.077	20	1.155	20	1.270
30	1.004	30	1.029	30	1.078	30	1.158	30	1.274
40	1.004	40	1.030	40	1.080	40	1.160	40	1.278
50	1.005	50	1.031	50	1.082	50	1.163	50	1.282
4.	1.005	10.	1.032	16	1.084	22	1.166	28	1.286
10	1.006	10	1.033	10	1.086	10	1.168	10	1.290
20	1.006	20	1.034	20	1.087	20	1.171	20	1.294
30	1.007	30	1.035	30	1.089	30	1.174	30	1.298
40	1.007	40	1.036	40	1.091	40	1.177	40	1.302
50	1.007	50	1.038	50	1.093	50	1.180	50	1.307
5.	1.008	11.	1.039	17	1.095	23	1.183	29	1.311
10	1.009	10	1.040	10	1.097	10	1.186	10	1.315
20	1.009	20	1.041	20	1.099	20	1.189	20	1.319
30	1.100	30	1.042	30	1.101	30	1.192	30	1.324
40	1.011	40	1.044	40	1.103	40	1.195	40	1.328
50	1.011	50	1.045	50	1.105	50	1.198	50	1.333
								30	1.337

If the decimal part of the value of R in the above table is increased by one per cent., the resulting values will be very nearly correct, in case the visual lines $a\ b$ and $a\ c$ form an angle of 35 minutes, or when they intercept one foot on the rod for each one hundred feet of distance.

Instead of the moveable telemeter wires described in the article referred to above, I prefer fixed wires, attached to the same ring and in the same manner as the ordinary cross wires, because with them there is less liability to error on the part of the man at the instrument.

Messrs. Young & Sons attach to their transits a very neat device for obtaining approximate measures of distance and elevation, which may be described as a micrometer tangent screw for measuring vertical angles. It is, however, not so accurate for horizontal distances as are the telemeter wires.

GEO. B. LAKE.

N. TOPEKA, Kansas, Feb. 4, 1875.

—*Railroad Gazette.*

Magnetism.

Among the many wonderful phenomena of nature, few are clothed with so much importance to the surveyor and mariner, or shrouded in so great mystery, as the manifestations of the terrestrial force which we call magnetism. The ancient Greeks and Romans were aware of the existence of this force, but ignorant of its practical value; and it was not until in the 11th and 12th centuries that the force of polarity imparted by the magnet to a moveable body susceptible of its influence, became generally known among the nations of Western Europe. That ancient and interesting people, the Chinese, to whom nothing, even of modern invention seems new, were, however, in the very earliest ages of the world's history acquainted with the directive power of the magnet, and used it to indicate the south, not in navigation but in land traveling. In the anterior part of the magnetic wagon a freely floating needle moved the arm and hand of a small figure, which pointed towards the south, and as late as the 15th century of our era, or 2,600 years after its first notice, the magnetic wagon was in use. In the beginning of the 12th century, A. D., the Chinese improved on the floating needle, and were, by means of the more perfect apparatus, enabled to determine the amount of the Western variation; and they also adapted the compass to maritime purposes, and in the 4th century, A. D., their vessels, under its guidance, visited Indian ports and the eastern coast of Africa.

Either the Arabs or the crusaders introduced the compass in the West in the 12th century, and there can scarcely be a doubt that the general application of the magnetic needle, by Europeans, to oceanic navigation, originally proceeded from the basin of the Mediterranean. The amount of the magnetic variation was known at a very early date, and was determined mainly by observations on the polar star. On the 13th of September, 1492, Columbus determined astronomically the line of "no variation" to be 2½° east of the Island of Corvo, in the Azores.

About the close of the 16th century, Wm. Gilbert first laid down comprehensive views of the magnetic force of the Earth, and he was the first in Europe who showed that iron might be rendered magnetic by being touched by the magnet, a fact which the Chinese had learned fully 500 years previously. The researches of Edmund Halley and others, in the 17th century, added a more thorough knowledge of the position of the lines of variation, and the first theoretical attempt to determine the position of the magnetic poles. In the 18th century the horary periodical variations of the needle were first discovered, and also the difference of intensity of terrestrial magnetism at different points of the earth's surface. The 19th century, distinguished for the great advancement of knowledge on almost every subject, has been especially productive of valuable results of organized and thoroughly scientific research in the field of Magnetism. Passing over the particulars of what has been done, we may sum it up in twelve objects which present themselves most prominently to our observation.

Two MAGNETIC POLES, which are unequally distant from the poles of rotation of the earth, and are situated one in each hemisphere; these are points of our terrestrial spheroid at which the magnetic inclination is equal to 90°, and at which therefore the horizontal force vanishes.

The MAGNETIC EQUATOR, the curve on which the inclination (or dip)=0°

The LINES OF EQUAL DECLINATION, and those on which the declination = 0 (ISOGONIC LINES and LINES OF NO VARIATION).

The LINES OF EQUAL INCLINATION (ISOCLINAL LINES). The four POINTS OF GREATEST INTENSITY of the magnetic force, two of equal intensity in each hemisphere.

The LINES OF EQUAL TERRESTRIAL FORCE (isodynanic lines).

The DYNAMIC EQUATOR, an UNDULATING LINE which connects together on each meridian the points of the weakest intensity of the terrestrial force,

These twelve phenomena of terrestrial magnetism may be concentrated under three points of view—Intensity, Inclination (or dip), and Declination (or horizontal variation).

For a knowledge of the two former of these elements—Intensity, and Inclination—we must refer our readers to the different treatises on the subject,—for our purpose we need to consider only the third element, Declination.

As before remarked, this variation of the needle was well known to the Chinese in the 12th century of our era, and through their extensive commercial relations with other nations of that period, its use became known to Europeans, so that as early as 1436 the maps then published give the variation for different parts of the sea.

In the middle latitudes, throughout the whole northern magnetic hemisphere, the end of the magnetic needle which points to the north pole is most closely in the direction of that pole about 8h. 15m. A. M. From this hour until about 1h. 45m., p. m., the needle moves from east to west,—a movement which is general throughout the northern hemisphere whether the local variation be west or east—thence it retrogrades towards the east until midnight or 1 a. m., oftentimes, however, making a short pause about 6 p. m. In the night there is a slight movement towards the west until the minimum or eastern position is reached at 8h. 15m. a. m. It is very remarkable that when the needle changes its continuous western motion into an eastern movement, or conversely, it does not continue unchanged for any length of time, but it turns round almost suddenly, more especially by day, at the above named periods, 8h. 15m. a. m., and 1 h. 45 m. p. m.

It has also been observed that no point has been discovered, at which the needle does not exhibit a horary motion. The turning points or hours, also vary throughout the year according to the relative positions of the earth and sun, and the quantity of elongation varies accordingly.

By means of extended navigation and the application of the compass to geodetic surveys, it was very early noticed that at certain times the magnetic needle exhibited an extraordinary disturbance in its direction, which was frequently connected with a vibratory, trembling and fluctuating motion. It was customary to ascribe this phenomenon to some spherical condition of the needle itself, which it was recommended should be again more strongly magnetised.

These disturbances are now classed as *magnetic storms* and have been the subject of innumerable observations. They occur mostly between the hours of 3 a. m. and 5 a. m., and are hardly to be considered as of any account in ordinary surveying operations.

We will sum up the results of our knowledge of the Diurnal and Annual changes of Declination, in three laws, which are considered as fair approximations to the absolute truth.

1st Law. "The diurnal variations of the magnetic needle follow local time"

2nd Law. The pole of the needle which is least distant from the sun makes a double diurnal excursion in the following manner: It is at its maximum of western excursion four or five hours before the sun passes the meridian of the place; it then turns eastward with increasing celerity of which the maximum occurs near the passage of the sun through the magnetic meridian, and it reaches its limit of eastern excursion one or two hours after the said passage. As the sun declines the needle returns; and as the sun passes the inferior meridian there is repeated in the night the same variation as that which took place during the day, but restricted within narrower limits The limiting hours of the changes vary with the seasons, and are generally earlier in summer and later in winter; and the magnitudes of the excursions are in the proportion of the diurnal to the nocturnal arc."

3rd Law. The diurnal excursion of the needle is the sum of two distinct excursions, of which the first depends solely on the horary angle, and the second depends besides on the sun's declination. These two fluctuations being variously superimposed upon each other, produce by their interference all the phenomena of the ordinary diurnal and annual variations.

This subject is one full of interest not only to surveyors and navigators, but to every person who is curious to learn more about this most mysterious of natural phenomena, and we feel assured that a further acquaintance with it through the many valuable works relating to it, that are now published, would meet with rich rewards of knowledge.—*Condensed.*

Practical Mathematics.

PLANE TRIGONOMETRY.

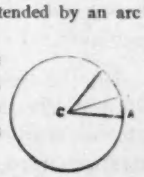
TRIGONOMETRY, as the name implies, was originally applied to that branch of Mathematics which furnished rules for the computation of triangles. In the present state of science it has a more extended signification, and is understood to embrace all theorems and formulæ which express the relations which exist between angles and certain quantities dependent on them, called Trigonometrical Functions.

As Geometry enables us to *construct* a triangle from three independent data, so Trigonometry enables us, from the same data expressed in numbers, to *calculate* its sides and angles. Triangles may be drawn either on a plane or spherical surface, and accordingly this branch of Mathematics is divided into *Plane* and *Spherical* Trigonometry.

THE ANGULAR UNIT.—The unit to which all angles are referred may be thus defined:

DEFINITION: The angular unit is that angle at the centre of a circle which is subtended by an arc equal in length to the radius.

With C as centre, and any line CA as radius, deescribe a circle. Let the arc AU be taken equal in length to the radius, and the point U joined with the centre—



The angle ACU=the Angular Unit.

CIRCULAR MEASURE OF AN ANGLE.—Any angle ACB may be expressed numerically, with reference to this unit, as follows:

Let A be the number which expresses its value; a the length of arc AB, which subtends it; and r the radius of the circle; then (Euc. VI. 33)

ACB : ACU :: arc AB : arc AU,

But ACU is the angular unit, and AU, by hypothesis is equal to the radius; therefore,

$$A : 1 :: a : r,$$

and therefore

$$A = \frac{a}{r}. \qquad (1)$$

This expression for the value of an angle is called its Circular Measure.

The Circular measure of an angle is the number which expresses the ratio of the arc which subtends it, to the radius of the circle.

In equation (1) three quantities, viz., A, a, r, are connected together, from which it follows, that if any two be given, the third may be calculated.

RATIO OF CIRCUMFERENCE TO DIAMETER.—The approximate value of the ratio of the circumference of a circle to its diameter has been determined by geometers to be

$$\text{Circumference} = 2\pi r \qquad (2)$$

where the Greek letter π (pi) = 3.14159 and $2r$ = dia.

CIRCULAR MEASURE OF A RIGHT ANGLE.—From equation (2) may be derived the circular measure of a right angle. The arc which subtends a right angle is equal to a fourth part of the circumference, or $\frac{1}{4}\pi r$. Dividing this by r, we obtain, by equation (1),

$$\text{Circular measure of a right angle} = \tfrac{1}{2}\pi.$$

SEXAGESIMAL DIVISION OF THE CIRCLE.—As the angular unit is not a submultiple of four right angles, and is, moreover, too large for practical purposes, such as astronomical observations and surveying, another mode of measuring angles, and representing them numerically, has been devised.

The circumference of the circle is divided into equal parts, called *degrees*, *minutes*, and *seconds*. In order to reduce an angle expressed in degrees, minutes, and seconds, to its circular measure, and *vice versa*, it is necessary to find the number of seconds in the angular unit:

Number of seconds in angular unit : number of seconds in four right angles :: arc AU : circumference.

Or,

Number of seconds in angular unit : $360 \times 60 \times 60$ :: r : $2\pi r$.

From which it follows, since $\pi = 3.14159$, that

Number of seconds in angular unit = 206265".

If A'' be the number of seconds in an angle which is subtended by an arc whose length is a, then

$$A'' : 206265'' :: a : \text{AU};$$

from which it follows, since AU = r, that

$$A'' = 206265'' \times \frac{a}{r}. \qquad (3)$$

$$= 57.3^{\circ} \times \frac{a}{r}$$

Or,

Number of seconds = 206265 × Circular Measure.

By equation (3), in which are connected together the radius, the number of seconds in the angle at the centre, and the length of the arc which subtends it, any two of these quantities being given, the third may be found.

Ex. It has been ascertained that the angle which the diameter of the earth subtends at the centre of the sun is 17".2. Calculate the sun's distance.

Ex. With a Rochon's micrometer I measured the angle which a gun-wheel in an enemy's battery subtends, and find it to be 12"; what is the distance of the gun, on the supposition that the wheel is 5 ft. in diameter? Ans. 1432 ft.